Army Guidance
Procedures for Forest Inventory
June 2006

1. Introduction

This guidance applies to all Army installations and facilities on federally owned and leased property with a current or potential for a Conservation Reimbursable Forestry Program. The purpose is to provide installations with information on the current options for creating, maintaining, updating, and utilizing forest inventories. Accurate forest inventories are essential for the development of a thorough forest management plan. Actual data collected for forest inventories will vary by installation depending on mission requirements and the size and quality of the forest resource. Installations following the provisions of this guidance will have forest inventories that provide a foundation for proactive management plans and decisions that are essential for sustaining effective training lands and fostering good ecosystem stewardship. Army Regulation 200-3 requires installations to perform forest inventories every ten years. Supplemental guidance (memorandum OACSIM, DAIM-ED-N, 17 Aug 99, subject: Army Regulatory Guidance for Reimbursable Agriculture/Grazing and Forestry Programs) provides that forest inventories will be utilized to support the installation Integrated Natural Resource Management Plan (INRMP) on forests essential to the mission and/or capable of forest product production. Inventory systems will be of an intensity that is appropriate for the planned use of the forest and for monitoring the long-term health and sustainability of the forest. Integrating forest inventories with vegetation communities planning level surveys is encouraged where a current or potential Conservation Reimbursable Forestry Program exists. This guidance does not apply to urban forests. This guidance is not intended for forests that do not have the potential for a Conservation Reimbursable Forestry Program.

Installations may use various inventory types detailed within this guidance to collect the required data elements, as well as other methodologies not included. The objective of the forest inventory is to collect information about the forested resource that can be utilized in scientific management of the forest and development of a forest management component of the INRMP. Installation level forest inventory is integral to the management and determination of the overall health and sustainability of the Army's Conservation Reimbursable Forestry Program and its ability to support the training mission. Forest inventory incorporation into each installation's forest management INRMP component provides an effective baseline for future generations of installation foresters.

As outlined in the 1999 Army Regulatory Guidance, Reimbursable Agricultural/Grazing and Forestry Programs, the purpose of the Conservation Reimbursable Forestry Program is to support the mission and ecosystem management, while optimizing the forest resource and its associated forest products and benefits. Proper forest inventories will help maximize the use of the forest resource to meet mission objectives, restore forest ecosystems, and support threatened, endangered and, at risk species.

Conducting and implementing forest inventories may initially increase direct program costs, but overall long-term benefits will outweigh these initial costs.

2. Reference Laws and Regulations

a. Sikes Act, Title 16 U.S.C. 670a (as amended by the Sikes Act Improvement Act 1997).

The Sikes Act requires each installation that possesses significant natural resources to prepare and implement an INRMP. No sale of forest products may be made unless the effects are compatible with the purposes of the INRMP.

b. Army Regulation 200-3—Natural Resources—Land, Forest and Wildlife Management, 28 February 1995. *(Consolidates AR 420-74—Natural Resources—Land, Forest and Wildlife Management and AR 210-9.)*

This regulation sets forth the policies, procedures, and responsibilities for Army forest management. The Army forest management program is required to support and enhance the immediate and long-term military mission while meeting stewardship requirements as mandated by federal laws. "It is the Department of the Army's policy to maintain, restore, and manage its forest lands on an ecosystem basis. The harvesting of forest products is allowed and encouraged when conducted consistent with protecting and maintaining a viable, self-sustaining ecosystem" (AR 200-3, Section 5-2a). AR 200-3 also requires that any installation that sells forest products must also prepare a Forest Management Component that is included in the INRMP. Note: AR 200-3 is planned for replacement by AR 200-1 in 2006.

c. Army Regulatory Guidance: Reimbursable Agricultural/Grazing and Forestry Programs, 17 August 1999.

This guidance supplements AR 200-3 to further the integration of the Conservation Reimbursable Forestry Program with mission, compliance, and ecosystem management efforts. Installations involved with the Conservation Reimbursable Forestry Program must: support the mission; comply with applicable laws and have an approved INRMP developed in accordance with National Environmental Policy Act (NEPA); be a fiscally sound investment and capable of ecosystem sustainability; comply with installation safety restrictions; and consider the potential effect on significant archeological resources and historic properties per AR 200-4.

d. Audit of Army Forestry Program – AA 01-420 Dated 22 August 01

The Army Audit Agency concluded that methods used for forest inventories were inconsistent, and that Army guidance was not available. It also concluded that the Army had no assurance that inventory results satisfied minimal requirements for forest management. The audit recommended that guidance "clarifying inventory requirements for ecosystem management, including the need to ensure the statistical validity of the data" should be distributed to ensure installations used appropriate inventory methods commensurate with their forestry needs.

3. Forest Inventory

The planning of a forest inventory should be coordinated across all land utilization units at the installation. The benefits of a forest inventory go beyond natural resource managers and can be utilized by the G3, Integrated Training Area Management (ITAM), and other environmental organizations to facilitate effective land management. Comprehensive forest inventories shall be conducted every ten years and updated after all major land management activities.

4. Forest Inventory Classes

There are three basic classes of forest inventories: assessment, continuous, and pre-management. Following is a discussion of each class of inventory and its appropriateness.

a. Assessment Inventory

The purpose of establishing an assessment forest inventory is to precisely determine the species composition and volume of all forestlands on an installation. Information gathered through the assessment inventory can be utilized to determine current forest conditions and facilitate short- and long-term ecosystem planning activities. Assessment inventories are required for the development of forest management plans, INRMPs, and predictive forest modeling. Assessment inventories can also be used to determine the availability of timber for harvest.

b. Continuous Forest Inventory (CFI)

The purpose of continuous forest inventory (CFI) is to acquire data to support broad-based management decisions, long-range planning, examine patterns and rates of forest succession, and measure tree growth and mortality. Long-term observations can quantify levels and dynamics of natural forest structures to be used as guides in ecosystem management. CFI can also provide a definitive measure of long-term productivity and, thus, sustainable harvest levels. Installations with 20,000 acres or more of managed forestlands can justify the establishment of CFI plots, since completing an installation-wide assessment inventory would be more expensive then re-measuring the existing CFI plots. The type of inventory utilized is determined based on overall management objectives. CFI should be done to capture trends occurring over long periods of time.

Permanently located plots are recommended when conducting a CFI. Repeated inventories over time and on the exact same location are instrumental in the analysis of environmental trends, such as determining growth rates of specific tree species. This information can be used in predictive growth models, a tool to help facilitate long-term ecosystem planning (see Section 12).

At a minimum, permanent plots should be measured every ten years. Permanent plots are placed at a frequency so that the results of the CFI are statistically valid and allow for a representative sample of all forestlands on the installation. CFIs require relatively few plots and are designed to have the information aggregated to large administrative units (e.g., training units) rather then by forest management units (e.g., stands).

c. Pre-management Inventory

The purpose of a pre-management inventory (e.g., timber cruise) is to obtain the most current estimate of timber volume, species composition, and value grade of a particular management unit prior to forest product removal. Pre-management inventories are used to determine an appraised value of the trees. Pre-management inventories can also update and configure growth and yield calculations of various forest attributes. Pre-management inventories should almost always precede normal silvicultural prescriptions. During a pre-management inventory, trees can be marked for leave and/or for removal.

5. Minimum Inventory Data Elements Standards

Army forest management requires a certain level of data collection for efficient resource management. Other environmental proponents, G3, and other tenant activities may require additional data elements for effective forest management and to support the mission. The following list describes standard plot- and tree-level elements utilized for all types of forest inventory. The list is intended to provide a baseline from which installations foresters may select, modify, or add elements to accommodate the installation specific needs and resources. Not all elements in the list are collected in every inventory class. For each inventory class, plot-level and tree-level data are averaged to determine stand-level data. Tables 1 and 2 on pages 7 and 8 identify which elements are collected in each inventory class.

Prior to collecting inventory data, the forest should be subdivided into distinguishable stands of similar characteristics that can be uniquely described in the inventory database. Primary characteristics requiring separate delineation include species, age, tree size, and density. Stands should be delineated on aerial photos prior to conducting the field inventory. Stand boundaries should be further delineated based on the field inventory. The minimum number of acres definable as a stand is two acres; however, the average stand size should not be less than five acres. Along with environmental elements, military training compartments and other existing boundaries should be considered when distinguishing stands.

a. Plot-Level Elements.

(1) Forest Type - A classification of forestland based upon the tree species or tree communities that constitute the majority of stocking on the site.

(2) Stand Age - The average age of live trees not overtopped in the predominant stand size-class. Stand age is usually highly correlated with stand height and should reflect the average age of all trees that are not overtopped. Only one or two dominant trees within a stand need to be bored to determine overall stand age.

(3) Stocking or Density Class - The relative degree of occupancy by trees, measured as basal area or the number of trees in a stand by size or age and spacing as compared to the basal area or number of trees required to fully utilize the growth potential of the land, or the stocking standard.

(4) Site Index - A species-specific measure of actual or potential forest quality, expressed in terms of the average height of trees included in a specified stand. Site index is estimated by determining the total height and age of dominant and co-dominant trees in a well-stocked, even-aged stand. When age and height have been determined they can be used as coordinates to interpolate height at a certain age, usually 25, 50, or 100 years. Site index is primarily a function of tree species and soil type. Coarse resolution site index estimates can be determined from soil maps published by the Natural Resources Conservation Service (NRCS).

(5) Slope - The average slope of the plot, usually expressed as a percent.

(6) Soil Type - Type of soil on the plot, which can be determined in the field or from pre-existing maps or from published NRCS soil surveys.

(7) Disease/Damage Indicators - Description of disease or infection, insect, invasive plants, or mechanical damage agents affecting a large portion of the plot. Describe characteristics and identify disease, damage, and or infection, and the percent of the plot affected.

(8) Understory Vegetation - General comments on abundance and species mix of understory vegetation. More specific information can be detailed in fixed subplot measurements.

(9) Forest Regeneration - Count of seedlings/saplings under one inch in diameter.

(10) Forest Management Class - Classification of the reimbursable forest use of the stand. Definitions include

- Manageable - Lands on which reimbursable forestry can be practiced with little or no limitations

- Non-manageable- Land on which reimbursable forestry cannot be currently practiced including, right of ways, ponds, drop zones, firing points, military impact areas, etc.
- Manageable with limitations - Lands on which reimbursable forestry is practiced but with limitations. These limitations can include stands that serve the military mission, those with metal-contaminated wood products, ecological restrictions, and/or limited access. Most stands on installations with military training missions will have limitations.

b. Tree-Level Elements

(1) Tree Number - A code to uniquely and permanently identify each tree on a given inventory plot. The tree numbers must be unique within a plot – being unique is more important than being sequential. In general, work clockwise from azimuth 001 to 360, and work outwards from plot center to plot edge.

(2) Tree Species - Species code or scientific name of a measured tree.

(3) Diameter at Breast Height (DBH) - Tree diameter at 4.5 feet above the ground line on the uphill side of the tree. Measurements should be taken to the nearest tenth of an inch for permanent plots and can be calculated in 2-inch classes for assessment and pre-management inventories.

(4) Total Tree Height - Total height of the tree, to the nearest 1.0 feet from the ground level to the tip of the apical meristem. For trees growing on a slope, measure on the uphill side of the tree. If the tree has a broken or missing top, estimate what the total length would be if there were no missing or broken top. Forked trees should be treated the same as unforked trees.

(5) Merchantable Tree Height - The height of the tree from stump height (1 foot) to the point on the bole above which the diameter is below the minimum merchantable diameter. Minimum merchantable diameter is dependent on the region and wood product.

(6) Crown Class - The measurement is equal to the tree crown's relation to sunlight received and proximity to neighboring trees. Five basic classes are:

- Open Grown: Trees with crowns that received full light from above and from all sides throughout most of their life.
- Dominant: Trees with crowns extending above the general level of the canopy and receiving full light from above and partly from the sides. These trees are taller than the average trees in the stand and their crowns are well developed. Their crown form or shape appears to be free of influence from neighboring trees.
- Co-dominant: Trees with crowns at the general level of the crown canopy. Crowns receive full light from above but little direct sunlight penetrates

their sides. Usually they have medium-sized crowns and are somewhat crowded from the sides. In stagnated stands, co-dominant trees have small-sized crowns and are crowded on the sides.

- Intermediate: Trees that are shorter than dominants and co-dominants, but the crowns extend into the canopy of co-dominant and dominant trees. They receive little direct light from above and none from the sides. As a result, intermediates usually have small crowns and are very crowded from the sides.
- Overtopped: Trees with crowns entirely below the general level of the crown canopy that receive no direct sunlight either from above or the sides.

(7) Crown Height - The overall distance from the bottom of the crown to the top of the crown.

(8) Crown Area - The area of the crown is calculated as 1/3 multiplied by the area of the base of the crown multiplied by the crown height.

(9) Tree Condition - An overall assessment of tree health — records if the tree is alive, dead, or diseased, etc.

(10) Tree Quality - A measure of individual log quality, usually used for pre-management cruises. Typical measurements are peeler, sawlog 1, 2, and 3, chip-n-saw, and pulpwood. In permanent and assessment inventories, measurements such as acceptable and unacceptable growing stock (AGS, UGS, respectively), cull, and dead can be used.

(11) Diameter Growth - Rate of diameter growth over previous five years.

(12) Damage Class - Record of tree damage to include all disease and other damage to the tree include lighting strike, scarification, logging damage, etc. Damage is characterized according to three attributes: location, type, and severity. The record should also include the amount or percentage of the tree that is affected by the damage.

TABLE 1: PLOT-LEVEL DATA FOR CONSIDERATION

Plot-Level Data	**Inventory Type**		
	Assessment	Continuous	Pre-management
Plot Number	X	X	X
Plot Location	X	X	X
Forest type	X	X	
Stand Age	X	X	
Stocking or density class	X	X	Yes. If partial cut is being done
Site Index	X	X	
Slope	X	X	
Soil Type	X	X	
Disease Indicators	X	X	
Understory Vegetation	X	X	
Forest Regeneration	X	X	

TABLE 2: INDIVIDUAL TREE-LEVEL DATA FOR CONSIDERATION

Individual Tree-Level data	**Inventory Type**		
	Assessment	Continuous	Pre-management
Tree Number		X	
Species	X	X	X
Diameter at Breast Height	X	X	X
Total Height	Optional	X	Optional
Merchantable stem lengths	Optional	X	X
Crown Class	Optional	X	
Crown Height	Optional	X	
Crown Area	Optional	X	
Tree Mortality	X	X	X
Tree Quality	X	X	X
Diameter Growth	X	X	
Damage Class	X	X	X

6. Inventory Collection Methodologies

Forest inventory data have been collected for over 100 years using classic methods such as prism, variable radius, and fixed-radius plot cruises. These methods are based on statistical inference of larger areas from a small sample of measurements. The most important part of every inventory method is that the collected data are consistent, accurate, and in an easily usable format. New technologies will continue to be developed (see paragraph 8), but classic methods can always be used. It is the role of the installation forester to decide which method best fits the objectives for the installation.

7. Sampling Method and Considerations.

Classic forestry inventory is done using a sampling process. A representative sample is inventoried and the results are extrapolated across the remaining inventory area. An efficient sampling scheme considers the sampling method (e.g., simple random, systematic, stratified random, etc.), sample size or intensity, and plot size. Regardless of the inventory objective, the method of selecting a sampling scheme is based on the concept of sampling probability.

a. Sampling Method.

(1) Simple Random Sampling: Simple random sampling assumes every possible combination of sample units has an equal and independent chance of being selected. This means that the probability of selecting any sample unit is independent of the selection of other units. For forest inventory, this sampling scheme has a low level of efficiency, since many areas of the forest may be missed and the samples collected could misrepresent actual forest conditions.

(2) Systematic Sampling: Systematic sampling starts with the selection of an initial sample unit, then the remaining sample units are placed at uniform intervals throughout the remaining tract of land, such as measuring a plot every 8 chains on a grid pattern. Typical spacing is dictated by the size of the sample plot as well as the intensity of the inventory required. Systematic sampling can be efficient because sample units are easy to locate on the ground and they can be more representative since they are uniformly spaced over the entire tract.

(3) Stratified Random Sampling: Stratified random sampling divides a given tract into sub-compartments of known size, based on homogenous descriptors such as stands, and then a random sampling of the sub-compartments is conducted. This method can be used to target variations within a given tract so that the random sampling is able to detect natural variations within the tract.

b. Sampling Size (Intensity).

In planning a forest inventory, regardless of the methodology implemented, sufficient sampling units should be measured to obtain the desired state of precision. A rule of thumb is to conduct a forest inventory to provide the best precision in terms of confidence limits on the estimated collected data for the lowest cost. Typical forest inventories sample 2-5% of the tract. To determine the approximate number of sample plots needed for statistical significance (sampling error of less than 20%), use the following set of calculations. However, a minimum of three points should be made in each forested stand regardless of size. Larger stands or stands with greater variability may require more sampling points to attain the desired sampling error.

Number of Plots = $(ts / E)^2$ Where
t = Standard error of the mean
s = Estimated standard deviation
E = Desired half-width of the confidence interval

This formula estimates the number of plots necessary to obtain an inventory that is statistically acceptable and efficient. Solving the formula requires an estimate of the standard deviation expressed in the same units as the desired precision E. The estimate may be obtained by measuring a small preliminary sample of the population or by using the standard deviation obtained from previous measurements. For a 95 percent level of confidence, *t* can generally be set to 2.

This computation can be complicated, as not all of the variables are predetermined, and can be difficult to estimate. There are some general rules of thumb for determining the number of plots necessary to ascertain accurate inventory data. In general, for smaller areas (less then 200 acres) the following calculation can be used.

$$\frac{\text{(Area of Tract) * (\% Cruise)}}{\text{(.005454) * (Average DBH)}^2\text{ * (BAF)}} = \text{Number of Points Necessary}$$

c. Plot Size.

At a given scale of measurement, small sample plots usually exhibit more relative variability (i.e., larger coefficient of variability) than larger plots. The relation of plot size to variability does differ from tract to tract. In general, large plots tend to have less relative variability because they average out the effect of tree clumps and stand openings. In uniform populations (e.g., plantations), changes in plot size have little effect on variability. Overall, plot size should be chosen based on experience, efficiency, and the inventory objective.

8. Evolving Forest Inventory Techniques.

New forest inventory technologies that can be utilized to rapidly develop forest inventories and improve the range of data continue to emerge. These advancements could derive tree level or canopy level forest attributes from remotely sensed data.

New technology should not completely replace ground-based forest inventories, but should be used in conjunction with classic forest inventory techniques, especially pre-management cruises and continuous forest inventories. Inventories based on remote sensing are not designed to be exact measurements but are done to provide a snapshot of current forest conditions.

It is imperative to understand the desired objectives of the completed forest inventory before moving forward with data collection efforts. Army foresters are encouraged to explore and implement innovative forest inventory technologies which may improve effectiveness in understanding the forest resource in terms needed for mission support, ecosystem management, and other purposes.

9. Conservation Considerations

Conservation of the diverse forest species array, including threatened and endangered species, should be considered when developing a plan for conducting a forest inventory. In order to ensure compliance with the Endangered Species Act (ESA) and the habitat requirements for native plants and animals, certain forest stand structure elements should be collected to monitor habitat requirements. For ESA listed species, specific requirements are outlined in recovery plans, biological opinions, and other information produced by the U.S. Fish and Wildlife Service. Installation biologists should be consulted prior to conducting forest inventories.

Installations with red-cockaded woodpecker (RCW) populations will consider accommodating RCW foraging habitat in forest inventories. This should be a collaboration between foresters and biologists and a combination of resource streams.

10. Information Management.

Data from forest inventories should be entered into some form of information system, e.g., Microsoft Access, Geographical Information System (GIS), or Oracle. There are four essential elements to efficient information management:

- An input form that provides for efficient collection of data for storage.
- A process that incorporates mathematical and logical processes to get from input to output.
- An output that presents desired information in a usable format.
- A process to update the database.

It is imperative that the collected forest inventory data be utilized as input for forestry and land use (e.g., military training) decisions that need to be made at the installation based on the needs of the mission, ecosystem, etc. and has the ability to be disseminated to other natural resource and Army functional units.

11. GIS and Global Positioning Systems (GPS).

Along with forest inventory data, GPS data should be collected to give spatial connectivity to the forest inventory. Spatial data features that should be collected include unit boundaries, road and stream locations, endangered species habitat areas, cultural resource areas, and any other significant natural areas or political boundaries. The GPS data should then be entered into a GIS. The resulting GIS data layers should be interconnected with the forest inventory data as well as other significant data that can impact forest management decisions. All GIS data should be in compliance with the following GIS requirements as outlined in Army guidance (memorandum, OACSIM

DAIM-MD, 16 Aug 01, subject: Data Standards for Computer Aided Design (CADD) Geographic Information System (GIS) and Related Technologies).

a. Data Documentation. All GIS data will be documented in accordance with the Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata.

b. Data Sharing. The National Spatial Data Infrastructure (NSDI) and Executive Order 12906 state that all GIS data will be shared to avoid wasteful duplication and promote effective and economical management of resources.

c. Data Standards. The Spatial Data Standard for Facilities, Infrastructure and Environment (SDSFIE) shall be followed for geospatial database table structure, nomenclature, attributes, and symbology to allow for data integration.

d. Projections and Datums. All GIS data shall use North American Datum (NAD) of 1983, or World Geodetic System (WGS) of 1984 coordinate system datums, and the North American Vertical Datum of 1988 (NAVD88) to ensure data alignment and accuracy.

e. Data quality. All GIS data shall be created and maintained at a quality and resolution that ensures accuracy and usefulness for installation management and mission support.

12. Predictive Forest Modeling - Growth and Yield Models.

Forest management decisions are predicated on information about both current and future resource conditions. Forest inventories provide information about the current state of the forest resource in terms of timber volumes and other related statistics. Forests are dynamic biological systems that are continually changing, and it is necessary to project these changes to obtain relevant information for prudent decision-making.

Stand dynamics, such as the growth, mortality, reproduction, and associated changes in the stand, can be predicted through direct and indirect methods. Direct methods based on past experiences are limited in application. It is necessary to utilize indirect methods of predicting stand dynamics through inference from the study of other stands. The inferences are derived from the use of tables and equations, within growth and yield models. The purpose of the growth and yield model is to produce estimates of stand characteristics at specified points in time. Growth and yield models can forecast future stand characteristics of treated and untreated stands. The growth and yield forecasts can be for short- or long-term projections and be aggregated to stand-level predictions or maintained at the individual-tree level.

Key elements of growth and yield models include the ability to be used in the specific region where the installation is located. Growth and yield models should also have the ability to produce outputs at the level desired for management and land use decisions.

There are two types of growth and yield models: stand level and individual tree models. Individual tree models are designed to produce future attributes of individual trees only aggregated at the per acre level. This is a highly detailed model and should not be utilized for management decisions at the landscape level. Stand-level models have a more coarse resolution, and require less detailed stand level information (i.e., stand basal area, stand species composition, and average age). These models are more appropriate for landscape-level decision-making.

Other considerations to determine what growth-and-yield modeling system should be utilized include how the model was developed. The US Forest Service has developed numerous growth-and-yield models that are region-specific, well-tested, and improved-upon regularly. Growth-and-yield models also have been developed specifically for given areas by forest consultants or private industry. It is important to understand not only what the model will predict but also why and how the model is making predictions.

Overall, growth-and-yield models are just models or estimates of actual conditions. It is vital that the results of the model are not taken as exact figures, but rather used in conjunction with ground-based estimates. The idea of growth and yield models is simply to give an idea of what may happen, not exactly what will happen.

13. Decision Support Systems.

Decision Support Systems (DSS) can be used to analyze and focus the results of growth and yield models. A DSS is typically a computer program that interacts with the growth-and yield program to produce reports, determine the availability of critical habitat as defined by the Endangered Species Act, and monitor impacts of various silvicultural treatments in the present and future. A wide variety of DSS are available through commercial vendors as well as the US Forest Service. Each one has particular functions that are unique to the system and choosing one should be based on the needs and objectives of the particular installation. Some DSS also have the ability to utilize installation objectives from forest management and INRMPs. The DSS can be helpful in understanding what constraints are limiting to certain objectives as well as what objectives are not possible to achieve.

14. Funding Options.

Forest inventory expenses should be charged to the Conservation Reimbursable Forestry Account. Installations should also consider applying for DoD Forestry Reserve account funds for forest inventory expenses. Army accounts in Base Support, Real Property Services may be used if available.

15. Technical Assistance.

Technical assistance for creating, maintaining, updating, and utilizing forest inventories is available from National Guard Bureau, Installation Management Agency Region, the USDA Forest Service, US Army Corps of Engineers District Natural Resource Personnel, and/or the US Army Environmental Center.